IoT Framework for Smart Agriculture to Predict the Crop Yield

SHORT SYNOPSIS

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CERTIFICATE

I hereby declare that the short synopsis Title " **IoT Framework for Smart Agriculture to Predict the Crop Yield**" being submitted in fulfillment of the requirement for the degree of **Doctor of Philosophy in Computer Applications** under **School of Computer Applications** of Manav Rachna International Institute of Research & Studies, Faridabad during the academic year 2023-24.

It is a bonafide record of original work carried out under the supervision of **Dr. Anupriya Jain**, Professor, School of Computer Applications and has not been submitted in full or part to any other university or institute for a degree or diploma. Further, it is certified that long synopsis is plagiarism free and proof has been submitted.

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ABSTRACT

As the world's population grows, the agricultural industry is essential to the global economy. However, this sector faces several challenges, including water scarcity, soil degradation, and climate change. In recent years, the Internet of Things (IoT) has emerged as a promising technology for the agricultural sector, enabling farmers to monitor their crops' growth and optimize resource utilization. An efficient portion of cultivation is played by crop rotation, soil clamminess, air and surface temperatures, precipitation, and other elements or variables. Important soil elements include potassium, phosphorus, and nitrogen. A greater awareness of the operational environment—a dynamic combination of soil, crop, and weather conditions—as well as the operation itself is made possible by the information produced by the many sensors employed in modern agricultural operations. This leads to more accurate decision-making. The main goal of this study is to advance agricultural technologies. This study proposes an IoT framework for smart agriculture to predict crop yield using sensors and machine learning algorithms. The system will monitor various parameters in real-time and provide farmers with instantaneous information on crop output and growth, empowering them to decide on irrigation, fertilisation, and pest management in a sensible manner. The integration of the decision support system with automated farming technologies will reduce labour costs, increase efficiency, and improve productivity. The proposed IoT framework will lead to sustainable agriculture practices, lowering the amount of herbicides, fertilisers, and water used, resulting in reduced environmental pollution and improved soil health. Although the implementation of the proposed framework will require investment, the benefits in terms of improved crop yield, reduced labour costs, and sustainable agriculture practices justify the investment. It can potentially revolutionize the agricultural sector and contribute to food security and sustainable development.

Keywords: Crop Yield; Machine learning; Crop Prediction; Smart Agriculture System; Internet of Things

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1. INTRODUCTION

IoT is a state-of-the-art technology for the surveillance and control of devices all over the world. According to a recent survey conducted by the World Bank, it is estimated that over 50% of the food needs to be grown by 2050, according to the current population rate (Gupta, A., & Nahar, P. (2022)). Due to current climate conditions, it can be a challenging task. So, Crop yield can be enhanced by introducing an IoT approach in smart agriculture, where-in light, water, pH value, soil perspiration, and nutrients are the most essential components of crop growth. The lack of adequate facilities means that the secular farmers in a developing region cannot test the humidity, temperature, soil pH, and other essential soil elements (Arshad, J., Aziz, M., Al-Huqail, A. A., Husnain, M., Rehman, A. U., & Shafiq, M. (2022)). The main aim of the Smart agriculture system is to transform the entire agricultural process into a field of automation in which humans are not involved (Mohapatra, H., & Rath, A. K. (2021)). Because of numerous parameters and the very long process in smart farming, analytic prediction is hard and unfeasible. In such cases, the use of smart systems such as deep learning methods, machine learning techniques, and data mining methodologies can be offered as an alternative solution (Wang, P., Hafshejani, B. A., & Wang, D. (2021)). IoT-based smart farming uses data gathered from different sensors and parameters to make accurate measurements and better predict crop quality and productivity. Sensors play a prime role in a variety of applications, and sensors incorporate their own devices and monitor various applications these applications can be controlled using mobile applications (Rasooli, M. W., Bhushan, B., & Kumar, N. (2020)). Numerous sensors are used to record environmental factors or parameters crucial to crop prediction. Typical environmental parameters like temperature, carbon dioxide concentration, humidity, intensity, etc. are fetched every five minutes (Bu, F., & Wang, X. (2019)). The IoT has been used in agriculture to enhance crop yields, improve crop quality and lessen overall costs (Muangprathub, J., Boonnam, N., Kajornkasirat, S., Lekbangpong, N., Wanichsombat, A., & Nillaor, P. (2019)). Soil quality testing plays a main role in smart agriculture because it proposes harvests to farmers depending on the results of tests performed on the soil (Spandana, K., & KPL, S. S. (2017)). The IoT architecture makes it easy to produce data for large, remote agricultural areas as with machine learning algorithm, the same can be used to predict crops (Bakthavatchalam, K., Karthik, B., Thiruvengadam, V., Muthal, S., Jose, D., Kotecha, K., & Varadarajan, V. (2022)). The aim of this study is to predict the crops using essential parameters so that farmers can easily predict the particular crop for

their yield according to the data collected. Deep learning methods will be used to predict the crops and data mining methodologies will be used to collect the data at the end a recommender system will be implemented so that farmers can collect the data through a mobile application or from a website.

2. DESCRIPTION OF BROAD AREAS

As shown in Figure 3.1 the IOT is when the internet is connected with dumb objects to make them smart objects.

A) IoT in Smart Agriculture

During the previous few decagons, notable progress has been made in the discipline of the Internet of Things (IoT). “Sensors, actuators, refrigerators, televisions, vehicles, clothing, food, medicine, and literature are all examples of "things" in the Internet of Things”.

Figure 3.1 Internet of Things (IoT) [Self]

Agriculture employing IoT might be radical for humanity and the whole world. Smart agriculture is the use of present-time particulars and communication technologies to manage fields aiming to boost the quality, and the number of crops while remarkably reducing the amount of work required by humans. Smart agriculture, in a broader sense, encircles food production strategies that harness IoT, big data, and sophisticated analytical technologies. The IoT refers to the addition of sensors, automation, and analytical technologies to current agricultural activities. The sensors detect every detail of crop production, including soil moisture, light, temperature, humidity, and irrigation system automation.

Using Smart Agriculture as shown in Figure 3.2 :

- Sustainability increasing agriculture capacity and income.
- Adapting and constructing flexibility to change in the climate.
- Lower greenhouse gas emissions.
- Provides better product quality.
- Reduce manpower and have control over the risks.
- Help farmers conserve water.

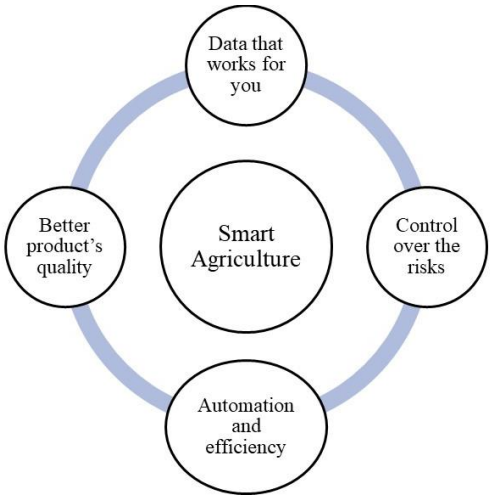

Figure 3.2 Smart Agriculture [Self]

B) Applications of IoT in Smart Agriculture

The primary uses of IoT-based smart farms are revolutionizing the agriculture sector now that have grasped the notion of smart farming. The following are some of the main applications as shown in Figure 3.3 of IoT that are used in Smart Agriculture:

i) Crop Management

Crop management is the procedure of examining the ecological, economic, and sociological factors that have a role in crop selection, marketing, and cultivation. Agricultural growth, the availability of water resources, labor costs, insurance costs, and other environmental factors all influence agricultural patterns. Traditional staple crops like paddy agriculture, which require considerable water resources, cannot be supported in locations with declining water resources and groundwater tables. Following the selection of a crop, crop cultivation is an important consideration.

ii) Soil Monitoring

Soil monitoring plays a crucial part in farm decision-making. Soil salinity, pests, moisture, pH, Water availability and humidity all influence cropping patterns. Sensors in the field measure the soil temperature and the humidity, the results are then uploaded to the cloud for analysis. Farmers will be notified about a variety of parameters, and cropping patterns will be determined

depending on soil nutrient levels, salinity content, humidity, and temperature.

iii) Smart Irrigation

Smart irrigation is the technique of applying cutting-edge technology to improve crop quality and quantity while maximizing water usage. Irrigation systems are classified as either weather-based or soil moisture sensor-based. In soil moisture sensor-based irrigation systems, sensors embedded in the turf of trees accurately measure the amount of moisture in the soil.

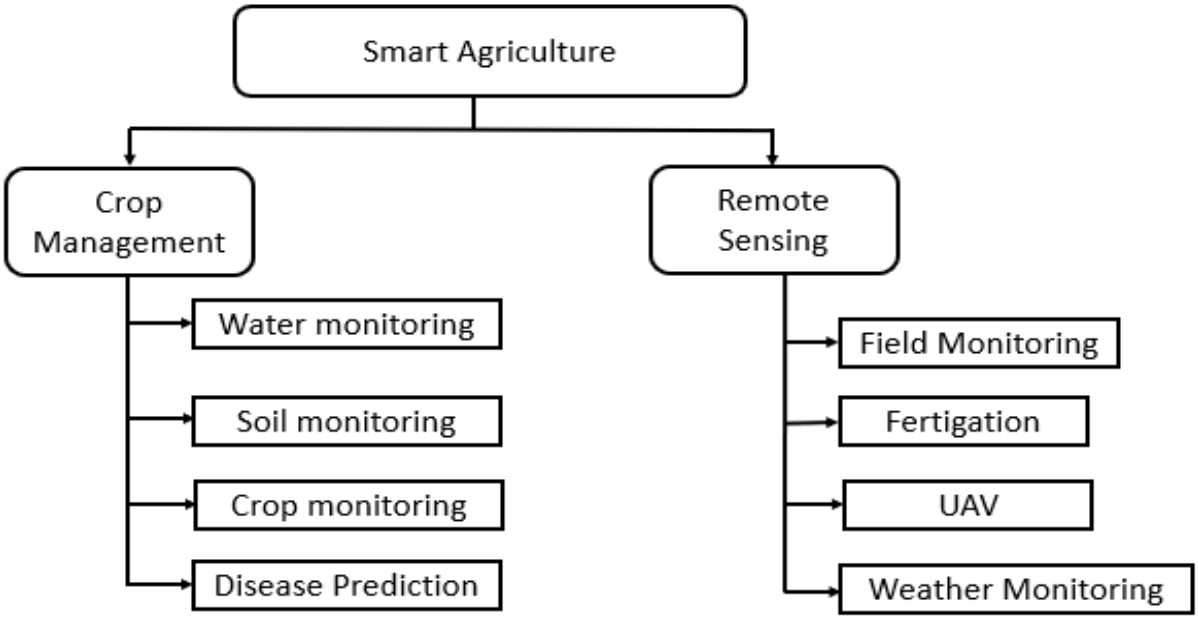

Figure 3.3 Applications of Smart Agriculture [Self]

iv) Remote Sensing

Drones that collect high-quality photographs to map farms can assist farmers to get real-time data on the crop utilizing remote sensing in agriculture. Drones can also be employed to examine crop yields by combining data on crop health and farmland condition. Farmers can utilize remote sensing to examine soil conditions and determine the type of soil which is best for a particular type of crop. Weather forecasting and monitoring are the most essential applications of remote sensing. Additionally, farmers may be forewarned in advance about

water availability and weather conditions so that crop planning can be done in advance by using remote sensing to monitor drought conditions, rainfall, and water supplies.

v) Unmanned Aerial Vehicle

The use of UAVs, often known as drones, has progressively increased in the modern agriculture economy. Crop mapping, remote sensing, fertigation, field monitoring, and weed detection are all examples of applications. Drones can come in handy for photographing big farming areas, mountainous terrain, or distant locations.

C) Challenges in Smart Agriculture

Smart Agriculture methods have revolutionized and simplified traditional agriculture. However, numerous obstacles remain to overcome before technologies may be widely adopted. The following are some of the key challenges in smart agriculture:

i) Hardware Availability

In order to sense diverse environmental and system properties, several sensors and devices are needed. Following the acquisition of data, the devices operate on the signals to provide a more predictable yield. In this circumstance, the availability of certain hardware represents a constraint.

ii) Hardware Security

The Internet of Things devices must be resistant to a variety of threats. The most prominent hardware security concerns for IoT devices are Trojan and Side-Channel Attacks, which limit IoT network adoption in key applications. Hardware Trojans take advantage of the adversary's malicious hardware modifications, which can also be used as a top-secret to control the system and launch attacks. Other Channel Attacks, which exploit side channel signals to recover secret information such as cryptographic keys, are another prominent hardware security concern.

iii) Power Issues

The farms are often large in size and require numerous electronic components, very high-power consumption is common. The majority of smart agriculture activities rely on huge equipment automation, which requires a lot of power to run. This has been a roadblock in large farms' adoption of automation procedures.

iv) Power Consumption

IoT devices must be powered by other power sources for the seamless, stable, and long-term functioning of the smart agricultural farm, the deployed models must be hungry for less power. They must be able to work in a low-resource environment.

v) Networking and Communication

One of the most common components of smart agriculture is machine-to-machine (M2M) interaction. This makes use of a variety of communication and network protocols to share information and collaborate on a common goal. A wide range of communication networks, including Wi-Fi, GPRS, LoRA, SigFox, and ZigBee, are used by the bulk of the apps. Initiating and maintaining such wide networks is expensive and impractical in big farms due to physical damages and risks.

vi) Data Security and Privacy

Robust encryption techniques and security measures are required to preserve data security and privacy during data transfer. In today's technologies, implementing security measures on a device with low resources is tough because the majority of smart agriculture procedures are automated, an opponent can control them to cause network havoc. This could have major effects on farm crop productivity and overall quality.

vii) Lack of Initial Capital Investment

The initial investment in new technologies is not usually possible in countryside areas of proveniences, as farmers work with a very low payback margin. It has the potential to slow down the widespread adoption of smart technologies.

3. LITERATURE REVIEW

Gupta, A., & Nahar, P. (2022), used two-tier ML methods called aKNCN and ELM-mBOA for predicting the crops according to the yield. To estimate the soil quality aKNCH model is proposed and the ELM model is proposed for other crop yield-based parameters i.e., temperature and rainfall. The proposed model is very complicated and complex for managing, planning, and building the different technologies of IoT. The proposed procedure can be used for different applications like plant management, livestock monitoring, crop and yield, soil monitoring, disease monitoring, and animal monitoring.

Research Gaps

A) The lack of clarity on the practicality and scalability of the proposed complex two-tier ML models (aKNCN and ELM-mBOA) for managing and planning IoT technologies in real-world agricultural settings. While the proposed models show promising results for predicting crop yield and estimating soil quality, it is unclear how they would perform in different environmental conditions, crop varieties, and farming practices.

B) There are limitations in implementing and maintaining these models due to the required computational resources and technical expertise. Therefore, future research could focus on exploring the practical implications of these models and evaluating their feasibility for wider adoption in the agriculture industry.

Arshad, J., Aziz, M., Al-Huqail, A. A., Husnain, M., Rehman, A. U., & Shafiq, M. (2022), next-generation tendencies, include superior soil preparation and intelligent irrigation systems, different methods of crop nutrient testing, intelligent fertilizer application, and double cropping practicesThe author employs an Android application and Wireless Sensor Network LoRa-based technology to focus on the environmental conditions for distinct crop yields. The proposed prototype can monitor different crop parameters at different regions or locations of

the farm. According to the researcher, the proposed prototype is a low-cost system and has auto-irrigation and auto-adjustment for different environmental factors. From a future perspective, a thermal imaging camera which is based on drone technology can be proposed to supervise the crop yield.

Research Gaps

A) The lack of clarity on the accuracy and effectiveness of the proposed prototype for monitoring and improving crop yields. While the use of Wireless Sensor Network LoRa-based technology and an android application is a promising approach, it is unclear how well the prototype can perform under different environmental conditions and crop varieties.

B) Other, the researcher suggests the use of a thermal imaging camera based on drone technology as a future perspective, but it is not clear how feasible and cost-effective this approach would be for widespread adoption in the agriculture industry. Therefore, future research could focus on conducting comprehensive field trials to evaluate the prototype's performance and compare it with existing methods of crop monitoring and management. Additionally, the research could explore other innovative approaches for improving crop yields, such as the use of precision farming technologies, precision irrigation, and crop modelling.

Mohapatra, H., & Rath, A. K. (2021), The study focuses on the new framework for smart agriculture which is IoE (Internet of Everything). A two-fold framework is proposed, the first is IOESA-the MIS and the second is SSA (Soil-Smart Agriculture analyzes analyze the soil quality. This framework can help farmers with crop selection based on the soil quality of their farms.

Research Gaps

A) The lack of clarity on the practicality and scalability of the proposed IoE-based framework for smart agriculture in real-world settings. While the framework shows promise for analyzing soil quality and helping farmers make informed decisions about crop selection, it is unclear how well it would perform under different environmental conditions, soil types, and farming practices.

B) Additionally, it is not clear how the framework would integrate with existing

agricultural infrastructure and technologies, such as precision farming systems and crop management software. Therefore, future research could focus on conducting field trials to evaluate the effectiveness of the proposed framework and explore ways to enhance its interoperability with other agricultural technologies. Furthermore, the research could also investigate potential barriers to adoption, such as cost, technical expertise, and data privacy concerns, and propose solutions to overcome these challenges.

Wang, P., Hafshejani, B. A., & Wang, D. (2021), According to the author, due to different varieties of parameters, the prediction is difficult and sometimes unfeasible in precision agriculture. So, the researcher proposed an improved MLP (Multilayer perception) technique to predict the amount of sugarcane production in agriculture based on IoT. The result shows a maximum accuracy of 99%. Three-layer artificial neural networks were evaluated for the procedure of changing sugarcane into sugar.

Research Gaps

A) The limited generalizability of the proposed MLP technique for predicting sugarcane production in different agricultural settings. While the technique shows a high level of accuracy in the specific context of the study, it is unclear how well it would perform in other regions, with different soil types, weather conditions, and farming practices.

B) It is not clear how the proposed technique would integrate with existing agricultural technologies and infrastructure, such as precision farming systems and crop management software. Therefore, future research could focus on exploring the applicability and scalability of the proposed MLP technique in diverse agricultural settings and evaluating its performance in comparison to other prediction methods. Furthermore, the research could investigate the potential for combining MLP with other machine learning techniques or data sources to improve the accuracy and generalizability of the predictions.

Goap, A., Sharma, D., Shukla, A. K., & Krishna, C. R. (2018), the researchers discussed that water scarcity is a major issue that is already affecting different areas of the world as circumstances are getting worse due to the enlarged population and need for fresh water. So, the researcher proposes a system that will save water in the agricultural area. Soil moisture is the primary consideration for a smart irrigation system since it is influenced by several

environmental factors. This research proposes an architecture for smart irrigation with a hybrid ML-based technique to forecast soil moisture. The proposed system is cost-effective and based on an open standard mechanism.

Research Gaps

A) The lack of clarity on the scalability and effectiveness of the proposed smart irrigation system in diverse agricultural settings. While the system shows promise for predicting soil moisture and optimizing irrigation, it is unclear how well it would perform in regions with different soil types, crop varieties, and weather conditions. Additionally, it is not clear how the system would integrate with existing agricultural infrastructure and technologies, such as precision farming systems and crop management software.

B) The need for more research on the long-term impact of smart irrigation systems on soil health and crop yield. While the proposed system can save water and optimize irrigation, it is not clear how it would affect soil health and crop yield over time. Therefore, future research could focus on monitoring the impact of smart irrigation systems on soil moisture, nutrient content, and crop growth over an extended period.

Rasooli, M. W., Bhushan, B., & Kumar, N. (2020), According to the authors, 80% of the Afghanistan population works in the agriculture sector. Agriculture plays an important role in any civilization as it gives basic needs like food and clothes. The aim of the author is to focus on the agriculture to control everything like irrigation, temperature, etc. by using WSN, Wi-Fi, or Zigbee modules for predicting the saffron and wheat crop parameters.

Research Gaps

A) The need for more research on the practical implementation and feasibility of IoT-based agricultural systems in developing countries like Afghanistan. While the use of IoT in agriculture shows potential for improving crop yields and reducing water usage, it is unclear how well these systems would perform in regions with limited infrastructure, resources, and technical expertise.

B) The lack of research on the social and economic impact of IoT-based agricultural systems on small-scale farmers in Afghanistan. While the proposed system can potentially improve crop yields and reduce water usage, it is not clear how it would affect the livelihoods of small-scale farmers who rely on traditional farming practices. Therefore, future research could focus on assessing the social and economic impact of

IoT-based agricultural systems on small-scale farmers in Afghanistan and identifying ways to ensure that these systems are accessible and beneficial for all farmers.

Bu, F., & Wang, X. (2019), The researchers proposed a deep reinforcement learning IoT-based with four layers i.e., agriculture data transmission layer, agriculture data layer, edge computing layer, and cloud computing layer to expand the food production and to improve crop growth environment.

Research Gaps

A) The need for more research on the practical challenges and limitations of implementing deep reinforcement learning IoT-based systems in agriculture. While the proposed system shows potential for improving food production and crop growth, it is unclear how well it would perform in real-world agricultural settings.

B) The lack of research on the environmental and sustainability implications of using deep reinforcement learning IoT-based systems in agriculture. While the proposed system can potentially increase food production, it is not clear how it would affect the environment and natural resources. Therefore, future research could focus on assessing the environmental impact of deep reinforcement learning IoT-based systems on soil quality, water usage, and other ecological factors, and identifying ways to ensure that these systems are sustainable and environmentally responsible.

Muangprathub, J., Boonnam, N., Kajornkasirat, S., Lekbangpong, N., Wanichsombat, A., & Nillaor, P. (2019), The researchers proposed WSNs applications to watering crops and introduced a system to handle environmental parameters in the crop yields. To enhance quality, reduce cost, and improve crop yield, IoT was used in agriculture. Three parts were used in the system i.e., hardware, web application and mobile application. The data mining technique by association rule was applied to get useful information regarding the environment and climate The study focused on the use of IoT for improving crop yield, but there was no specific focus on the type of crops. The research gap could be to investigate the effectiveness of the proposed system on different types of crops and their environmental requirements.

Research Gaps

A) The proposed system used association rule mining for extracting useful information regarding the environment and climate, but there was no analysis of the accuracy of the

extracted information. A research gap could be to evaluate the accuracy of the information obtained and compare it with other data mining techniques.

Sowmiya, E., & Sivaranjani, S. (2017), The researchers proposed a sensor-based system that will collect the data of PH, soil moisture, and temperature through sensors and provide that data to farmers for crop cultivation at a minimal cost. It will reduce the workload of farmers and give an alert on soil resources.

Research Gaps

A) Although the proposed system is aimed at reducing the workload of farmers and providing them with real-time information about their crops, it is not clear how the system will be implemented in terms of scalability and compatibility with different types of crops and farming practices.

B) The study does not provide any information on the accuracy and reliability of the sensor-based data collection system, which is a critical aspect of any IoT-based solution. It would be important to investigate the performance of the sensors in different soil conditions and their impact on crop yield.

Bakthavatchalam, K., Karthik, B., Thiruvengadam, V., Muthal, S., Jose, D., Kotecha, K., & Varadarajan, V. (2022), The researchers introduced a model for precision agriculture which predicts the high yield crop. The supervised learning method using machine learning in WEKA is used. The model can recommend different parameters like pH, K, N, P, Rainfall, Humidity, and Temperature. According to the author, the performance of this model is 98.2273%. This model can help farmers to decide the best yield crop by measuring the required parameters.

Research Gaps

A) While the proposed model shows a high accuracy rate, the study does not mention the size of the dataset used for training and testing the model. A larger dataset could help in validating the results and improve the generalizability of the model.

B) The study focuses on foresee the best yield crop based on various parameters. However, it does not consider the economic factors associated with cultivating a particular crop. Future research could incorporate economic analysis and provide recommendations that consider both the yield potential and profitability of cultivating a crop.

Colombo-Mendoza, L. O., Paredes-Valverde, M. A., Salas-Zárate, M. D. P., & Valencia-García, R. (2022), The researchers presents a design for a smart farming system to predict the crops in which IoT sensors, data storage servers, and cloud services are used, which are low-cost. To predict the crop a new data-mining method is proposed. The crop production prediction helps the farmers to make decisions on time.

Research Gaps

A) While the proposed smart farming system is claimed to be low-cost, no detailed cost analysis has been presented in the study. Further research can be conducted to evaluate the economic feasibility of the proposed system and its affordability for small-scale farmers.

B) The study proposes a new data-mining method for crop production prediction, but it does not provide a comparison of the proposed method with the existing methods. Further research can be conducted to compare the performance of the proposed method with other data-mining techniques in terms of accuracy and efficiency.

Singila, K. (2021), The author described that crop yield prediction can be very useful for farmers and the government as it will minimize the loss due to any disaster. In this research, many regression techniques are used and remote sensing techniques are used with the assistance of satellite imagery to predict the crops.

Research Gaps

A) While the author mentions the use of regression techniques and remote sensing for crop yield prediction, there is no discussion on the specific techniques used and their effectiveness. Future research could explore the comparative analysis of different regression techniques and remote sensing methods for crop yield prediction, and determine which approach is the most accurate and efficient.

B) The author discusses the benefits of crop yield prediction for farmers and governments but does not address the potential limitations or challenges associated with the implementation of such techniques. Future research could explore the socio-economic, environmental, and technological barriers to adopting and implementing crop yield prediction technologies, and provide strategies to address these challenges.

Kalimuthu, M., Vaishnavi, P., & Kishore, M. (2020, August), In this paper a supervised learning algorithm named Naïve Bayes is used to guide the farmers in sowing the crops according to the yields. With ML algorithms, data is collected for different parameters like humidity, temperature, and moisture. An Android mobile application is also developed. This will help farmers to select the most relevant crop for their yields.

Research Gaps

A) The suggested approach assists farmers in choosing the crop that would provide the highest yields, but it ignores other critical elements like soil type, nutrient content, and climatic unpredictability. Thus, further research can be conducted to integrate these factors into the model to make more informed crop selection decisions.

B) The study mainly focuses on the use of the Naïve Bayes algorithm and doesn't compare it with other machine learning algorithms. Therefore, a comparative study can be conducted to evaluate the effectiveness of Naïve Bayes against other popular algorithms such as Random Forest, Support Vector Machine, and Neural Networks.

Wolanin, A., Mateo-García, G., Camps-Valls, G., Gómez-Chova, L., Meroni, M., Duveiller, G., ... & Guanter, L. (2020), Due to climate change, there can be many challenges in the agriculture field. So, it is important to forecast crop yields beforehand. The researcher proposed deep learning and machine learning techniques. Deep neural network approach is used in the Indian wheat belt to forecast wheat crop production.

Research Gaps

A) The proposed deep neural network methodology is applied only for foresee wheat crop yield in the Indian wheat belt. Future research can explore the application of this methodology for other crops and regions to examine its generalizability and effectiveness.

B) The study focuses on using remote sensing data to predict crop yields, but it does not consider the impact of other important factors such as soil quality, water availability, and pest infestation on crop yields. Further research could incorporate these factors into the prediction model to improve its accuracy and practicality.

Arumugam, P., Chemura, A., Schauberger, B., & Gornott, C. (2021), For accurate and timely rice yield estimate, the researcher developed a unique method that incorporates remote sensing data using a machine learning methodology. The Gradient Boosted Regression (GBR) method may effectively scale the yields down. For the majority of India's states, this research reaches great accuracy.

Research Gaps

A) While the proposed method gives high accuracy for most states in India, it would be interesting to investigate the performance of the method in other countries or regions with different climatic and agricultural conditions.

B) The study focuses on rice yield estimation using remote sensing data and machine learning methodology. It would be beneficial to explore the potential of this method for estimating the yields of other crops as well.

Anakha Venugopal, Aparna S, Jinsu Mani, Rima Mathew, Vinu Williams, (2021), In this paper different methods of Machine learning are used for the prediction of crop yield. The author focuses on forecasting the yield crop by proposing a machine-learning approach. As classifier models, logistic regression, naive Bayes, and random forest are used; random forest offers the best level of accuracy.

Research Gaps

A) While the study highlights the use of different classifier models for predicting crop yield, it does not provide an in-depth analysis of the pros and cons of each model. Further research could be conducted to explore the strengths and limitations of various classifier models and to identify the most suitable one for crop yield prediction in different scenarios.

B) The study only focuses on the correctness of the machine-learning approach for crop yield prediction. Future research could explore other factors that affect crop yield prediction, such as the quality and type of data used, the impact of environmental factors, and the impact of different agronomic practices on crop yield.

Table 3.1 Summary of the analysis of previous research

Paper Title	Author Name and Year of Publishing	Methodology	Advantages	Disadvantages
"Classification and yield prediction in smart agriculture system using IoT"	Gupta, A., & Nahar, P. (2022)	aKNCN	Enhance the predictive system with a lower error value.	A very complicated model for the planning, management, and construction of global IoT technology.
"Implementation of a LoRaWAN Based Smart Agriculture Decision Support System for Optimum Crop Yield"	Arshad, J., Aziz, M., Al-Huqail, A. A., Husnain, M., Rehman, A. U., & Shafiq, M. (2022)	WSN-based DSS system and LoRa-based technology	Reduces the labor cost, increases the system accuracy, and a low-cost system.	Suitable for restricted locality and cannot retrieve data or information from encryption sensors.
"An improved multilayer perceptron approach for detecting sugarcane yield production in IoT-based smart agriculture"	Wang, P., Hafshejani, B. A., & Wang, D. (2021)	Multilayer Perceptron algorithm	The proposed approach has the greatest accuracy of 99%.	Complex approach
"Applicability of wireless sensor networks & IoT in saffron & wheat crops: A smart agriculture perspective"	Rasooli, M. W., Bhushan, B., & Kumar, N. (2020)	Zigbee, WSN and Wifi modules	Farmers are able to resolve problems like irrigation, temperature and humidity.	Focus only on limited crops
"IoT Framework for Measurement and Precision Agriculture: Predicting the Crop Using Machine Learning Algorithms"	Bakthavatchalam, K., Karthik, B., Thiruvengadam, V., Muthal, S., Jose, D., Kotecha, K., & Varadarajan, V. (2022)	Supervised learning method and WEKA classifier.	Help farmers decide which crop is best by simply measuring the necessary parameter.	Largest time taken to build model.
"Wheat crop yield prediction using deep LSTM model"	Sharma, S., Rai, S., & Krishnan, N. C. (2020).	Deep LSTM Model	Using publicly available satellite imagery, a reliable and economical approach for predicting crop yields has been developed.	
"Crop yield prediction techniques using remote sensing data"	Singila, K. (2021)	Machine Learning Regression, Support Vector Machine, Neural Network	The statistical models used to forecast yield have fewer parameters and are easier to apply.	These models only provide minimal information.
"Crop prediction using machine learning"	Kalimuthu, M., Vaishnavi, P., & Kishore, M. (2020, August)	NB (Naïve Bayes), Supervised learning algorithm.	High accuracy	Limited parameters
"Estimating and understanding crop yields with explainable deep learning in the Indian Wheat Belt"	Wolanin, A., Mateo-García, G., Camps-Valls, G., Gómez-Chova, L., Meroni, M., Duveiller, G., ... & Guanter, L. (2020)	Ridge regression and Random Forest	Satisfactory model performance	Very Complex
"Remote Sensing Based Yield Estimation of Rice (Oryza	Arumugam, P., Chemura, A., Schauberger, B., & Gornott, C.	Gradient Boosted Regression models	Feasible across India for timely rice yield estimation.	

Sativa L.) Using Gradient Boosted Regression in India"	(2021)			
"Crops yield prediction and efficient use of fertilizers using machine learning"	Mounika, N., & Reddy, D.V. (2021)	Machine learning algorithms	Obtained the highest efficient yield output.	No recommender system
"Crop Yield Prediction using Machine Learning Algorithms"	Anakha Venugopal, Aparna S, Jinsu Mani, Rima Mathew, Vinu Williams, 2021	Basic Classification techniques of machine learning	Help farmers decide which crop to grow to maximize yield.	Proper irrigation isn't there.
"A smart agriculture IoT system based on deep reinforcement learning"	Bu, F., & Wang, X. (2019)	Q-learning	Allows for intelligent decisions to adapt the environment to growing crops.	It cannot reach human performance by adapting to dynamic environments and resolving complicated tasks.
"IoE based framework for smart agriculture"	Mohapatra, H., & Rath, A. K. (2021)	IoE enabled Smart Agriculture Model and a Soil-Smart Agriculture Method to get the current soil quality.	Enhance the efficiency of crops selection based on the soil quality	Lack of basic infrastructure and Requirement of Internet
"An IoT based smart irrigation management system using Machine learning and open-source technologies"	Goap, A., Sharma, D., Shukla, A. K., & Krishna, C. R. (2018)	Hybrid ML approach with Smart irrigation system	Profitable because it relies on open standard technologies.	
"IoT and agriculture data analysis for smart farm"	Muangprathub, J., Boonnam, N., Kajornkasirat, S., Lekbangpong, N., Wanichsombat, A., & Nillaor, P. (2019)	WSNs application to watering crops	Great potential for applications of digital technology in farming.	Can be useful for limited crops
"A Survey on Soil Quality Testing using Sensors in Smart Agriculture for Crop Production and Maintenance using Internet Of Things (IOT)"	Spandana, K., & KPL, S. S. (2017)	Sensors Used for Soil Quality Testing	The machine suggests the cultivation for the farmers and it also helps them to maintain the cultivation.	
"Smart system Monitoring on soil using Internet of Things (IoT)"	Sowmiya, E., & Sivaranjani, S. (2017)	Soil Sensors	Very useful for farmers who are far from the ground, and enhances the crop.	
"Crop yield prediction using machine learning"	Champaneri, M., Chachpara, D., Chandvidkar, C., & Rathod, M. (2016)	Random forest algorithm, Data mining techniques	User friendly and the accuracy of predictions are above 75 per cent in all the crops.	Focuses on a particular state
"A hybrid approach for crop yield prediction using machine learning and deep learning algorithms"	Agarwal, S., & Tarar, S. (2021)	SVM technique of ML, LSTM and RNN techniques of DL	Most harvests yield under given conditions with less expense.	The farmers need to be educated
"Prediction of crop production in India using data mining techniques"	Jambekar, S., Nema, S., & Saquib, Z. (2018, August)	Random Forest and Multivariate Adaptive	Impact of different factors like precipitation, mean temperature, irrigated locality and area on field crop production.	Accurate forecast is required.

"Crop yield prediction with deep convolutional neural networks"	Nevavuori, P., Narra, N., & Lipping, T. (2019)	Deep learning technology – CNN (Convolutional Neural Networks)	Exceptional efficiency in image grading tasks.	Climate features and soil features are not there.
"Crop yield prediction through proximal sensing and machine learning algorithms"	Abbas, F., Afzaal, H., Farooque, A. A., & Tang, S. (2020)	Elastic net, k-nearest neighbor, and support vector regression. Linear Regression	Elements of Food Security Initiatives Around the World.	Large datasets are required
"Wheat crop yield prediction using new activation functions in neural network"	Bhojani, S. H., & Bhatt, N. (2020)	Multilayer perceptron of data mining	Provides better output when contrasted to the standard activation function "sigmoid" in agricultural datasets.	The dataset must be normalized when applying the classification technique.
"A novel approach for efficient crop yield prediction"	Gopal, P. M., & Bhargavi, R. (2019)	Neural Network and Regression based on Multiple Linear	The suggested hybrid MLR-ANN method offers higher accuracy than traditional methods.	Complex approach
"Machine learning prediction analysis using IoT for smart farming"	Rehman, A., Liu, J., Keqiu, L., Mateen, A., & Yasin, M. Q. (2020)	Field Sensors, Raspberry pi3.	Helps predict and predict future climate risks, accessible from anywhere, efficient and user-friendly.	Cannot predict the various parameters.
"A survey on deep learning based IoT approach for precision crop suggestion"	Priya, P. K., & Yuvaraj, N. (2019)	Neural Network based on AI and Deep Neural Network.	Helps farmers to take valuable decisions.	The proposed system can be improved by proposing timely fertilizers using a hybrid approach and achieving high profits and yields.
"Crop Recommendation on Analyzing Soil Using Machine Learning"	Anguraj, K., Thiyaneswaran, B., Megashree, G., Shri, J. P., Navya, S., & Jayanthi, J. (2021)	Machine learning algorithms	Minimum error and maximum accuracy.	
"Smart crop prediction using IoT and machine learning"	Gupta, A., Nagda, D., Nikhare, P., & Sandbhor, A. (2021)	IoT and Machine leaning algorithms	lessen the difficulties and problems occurred for the farmers and could boom the amount and exceptional of labor done.	Various parameters are missing.

4. GAPS IN THE RESEARCH STUDY

1. The parameters like (Soil type, Nutrient Levels, and climate variability) for crop prediction in previous works are incomplete.
2. The accuracy and effectiveness of the previously proposed prototype for improving crop yields are unclear.
3. There is a need for more study on the constraints and practical difficulties of deep reinforcement learning Internet of things systems in agriculture.
4. The scalability and effectiveness of the smart irrigation system in diverse agricultural settings is not clear in previous research.

5. RESEARCH OBJECTIVES

To boost production and efficiency, the agriculture sector is quickly implementing new technologies, such as the Internet of Things (IoT). A developing subject called "smart agriculture" makes use of Internet of Things (IoT) sensors and devices to monitor and regulate a variety of variables that affect agricultural productivity, such as temperature, moisture in the soil, and weather. By providing farmers with real-time data and insights through the usage of IoT, farmers may make well-informed decisions on pest management, fertilisation, irrigation, and other farming methods.

IoT Framework for Smart Agriculture:

The proposed IoT framework for smart agriculture consists of various sensors, IoT devices, and machine-learning algorithms that work together to monitor and predict crop yield. The framework involves the following components:

1. Sensors and IoT Devices: Soil moisture, temperature, humidity, weather sensors, and IoT gateways will be installed in the field to monitor various factors like soil moisture, temperature, humidity, and weather conditions, that impact crop growth. The sensors will collect data and send it to the cloud using IoT gateways.
2. Data Processing and Analysis: ML algorithms will be used to analyze the data collected from sensors and predict crop yield. The algorithms will use historical data, current data, and weather forecasts to predict future crop yields. The data can be processed in real-time, and the predicted crop yield can be displayed on a dashboard accessible by farmers.
3. Decision Support System: The dashboard will provide farmers with real-time insights into crop growth and yield. It will let farmers decide on irrigation, fertilization, and pest management in a knowledgeable manner. The system will also provide recommendations for the timing and amount of fertilizer to be applied and the timing of irrigation. It can also detect weeds and recommend appropriate measures.
4. Automated Farming: The decision support system can be integrated with automated farming technologies, such as precision agriculture, to automate the process of applying fertilizers, irrigation, and pest control measures. This will reduce labour costs and increase efficiency.

The main research objectives are:

1. To propose an IoT framework for smart agriculture to predict crop yield using sensors and machine learning algorithms.
2. To monitor various parameters in real-time and provide farmers with insights into crop growth and yield.
3. To increase efficiency and reduce labour costs by integrating automated farming technologies with the decision support system.
4. To develop a robust and accurate machine learning model capable of identifying and classifying various crop diseases from images, aiming to enhance early disease detection and facilitate timely interventions in agriculture practices.

The proposed IoT framework for smart agriculture can help farmers predict crop yield accurately by monitoring various parameters and taking appropriate actions. Farmers will be able to track temperature, humidity, soil moisture content, and meteorological conditions in real time with the use of sensors, Internet of Things devices, and machine learning algorithms. Farmers will get advice for pest management, fertilisation, and irrigation via the decision support system. The integration with automated farming technologies will reduce labor costs and increase efficiency. The proposed framework can lead to sustainable agriculture practices that are beneficial for the environment and the economy.

6. RESEARCH METHODOLOGY

The proposed IoT framework for smart agriculture to predict crop yield will be implemented using the following methodology as shown in Figure 6.1:

Step 1: Sensor Deployment

The first step in implementing the IoT framework is to deploy sensors and IoT devices in the field. Various sensors such as soil moisture sensors, temperature sensors, humidity sensors, and weather sensors will be placed in the field to monitor various parameters. These sensors will collect data in real time, which will be sent to the cloud using IoT gateways. The sensors will be placed in such a way that they cover the entire field.

Step 2: Data Collection

The data collected from the sensors will be sent to the cloud using IoT gateways. The IoT gateways will be used to transmit the data from the sensors to the cloud. The data will be transmitted in real-time, ensuring that the farmers have access to the most up-to-date data.

Step 3: Data Processing and Analysis

Machine learning methods will be used to process and interpret the data gathered from the sensors. The algorithms will use historical data, current data, and weather forecasts to predict future crop yields. The algorithms will analyze the data in real-time, and the predicted crop yield will be displayed on a dashboard accessible by farmers.

Step 4: Decision Support System

The dashboard will provide farmers with real-time insights into crop growth and yield. Farmers will be able to decide on irrigation, fertilization, and pest management with knowledge. The system will also provide recommendations for the timing and amount of fertilizer to be applied and the timing of irrigation. The system will also be able to detect weeds and recommend appropriate measures.

Step 5: Automated Farming

The decision support system can be integrated with automated farming technologies such as precision agriculture to automate the process of applying fertilizers, irrigation, and pest control measures. This will reduce labor costs and increase efficiency.

Step 6: Evaluation and Improvement

The proposed IoT framework will be evaluated based on its performance in predicting crop yield accurately. Farmers' feedback will be collected to identify any areas that need improvement. Based on this feedback, the framework will be improved to ensure that it meets the farmers' requirements.

The proposed IoT framework for smart agriculture to predict crop yield will be implemented using a step-by-step methodology. The framework will consist of various sensors, IoT devices, and machine-learning algorithms that work together to monitor and predict crop yield. Farmers will be able to track temperature, humidity, soil moisture content, and meteorological conditions in real time with the use of sensors, Internet of Things devices, and machine learning

algorithms. The farmers will get advice for pest management, fertilization, and irrigation via the decision support system. The integration with automated farming technologies will reduce labor costs and increase efficiency. The proposed methodology can lead to sustainable agriculture practices that are beneficial for the environment and the economy.

Flow of Process

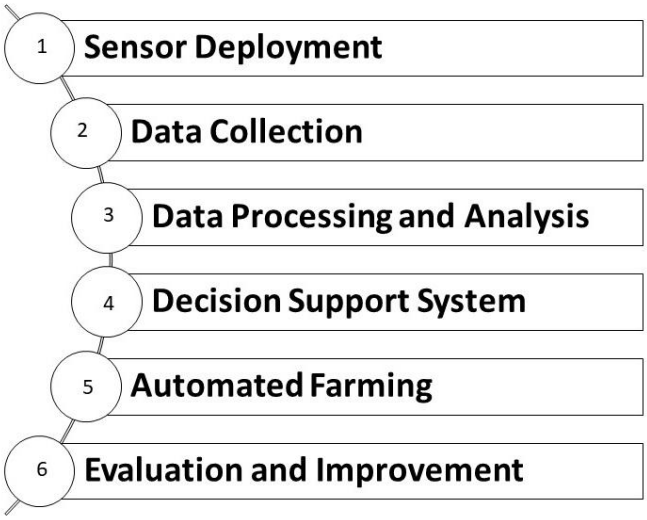

Figure 6.1 Research Methodology [Self]

7. EXPECTED OUTCOME OF THE STUDY

The proposed IoT framework for smart agriculture to predict crop yield is expected to have several outcomes, including:

1. **Improved crop yield**: The use of sensors and ML algorithms will enable farmers to monitor and predict crop yield accurately. The decision support system will provide farmers with irrigation, fertilization, and pest control recommendations, resulting in improved crop yield.
2. **Reduced labour costs:** The integration of the decision support system with automated farming technologies such as precision agriculture will reduce labour costs, increase efficiency, and improve productivity.
3. **Sustainable agriculture practices**: The use of the proposed IoT framework will lead to sustainable agriculture practices that are beneficial for the environment and the economy. The system will reduce the use of water, fertilizers, and pesticides, resulting in reduced environmental pollution and improved soil health.

4. **Timely monitoring and decision-making**: The use of real-time data and machine learning algorithms will enable farmers to monitor crop growth and make knowledgeable decisions regarding irrigation, fertilization, and pest control measures.
5. **Increased profitability**: Improved crop yield, reduced labor costs, and sustainable agriculture practices will lead to increased profitability for farmers.
6. **Scalability:** The proposed IoT framework can be scaled up to cover large areas of farmland, facilitating more effective agricultural monitoring and management by farmers.

The expected outcome of the study is to provide a comprehensive IoT framework that can be implemented by farmers to improve their crop yield, reduce labor costs, and promote sustainable agriculture practices.

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IoT Framework for Smart Agriculture to Predict the Crop Yield

SHORT SYNOPSIS
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ABSTRACT

As the world's population grows, the agricultural industry is essential to the global economy. However, this sector faces several challenges, including water scarcity, soil degradation, and climate change. In recent years, the Internet of Things (IoT) has emerged as a promising technology for the agricultural sector, enabling farmers to monitor their crops' growth and optimize resource utilization. An efficient portion of cultivation is played by crop rotation, soil clamminess, air and surface temperatures, precipitation, and other elements or variables. Important soil elements include potassium, phosphorus, and nitrogen. A greater awareness of the operational environment—a dynamic combination of soil, crop, and weather conditions—as well as the operation itself is made possible by the information produced by the many sensors employed in modern agricultural operations. This leads to more accurate decision-making. The main goal of this study is to advance agricultural technologies. This study proposes an IoT framework for smart agriculture to predict crop yield using sensors and machine learning algorithms. The system will monitor various parameters in real-time and provide farmers with instantaneous information on crop output and growth, empowering them to decide on irrigation, fertilisation, and pest management in a sensible manner. The

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